Quantum Numbers

Atomic Orbital

- A solution to Schrödinger's wave equation.
- The region of space where an electron spends 90% of its time.
- Can be described as an "electron cloud".
- Each orbital has a specific energy level, or shell.

Quantum Numbers

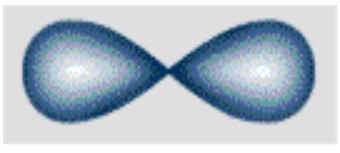
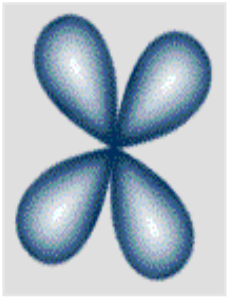
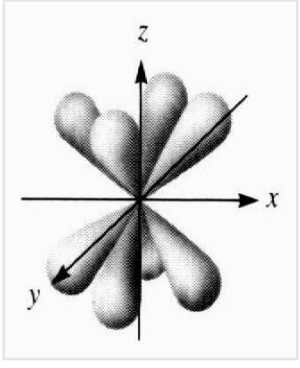
- Integer values that arise from the Schrödinger equation.
  - Three of which describe the distribution of electrons in the atom,
  - One that describes the spin of a given electron in the atom. (decimal)

1. The Principal Quantum Number (n):
   - Indicates the main energy level in which the electron is found.
   - Indicates the size of the orbital.
   - Allowed values: n = 1 to infinity.

2. The Angular Momentum number (azimuthal Quantum Number) (l):
   - Indicates the energy sublevels in which the electron is found.
   - It describes the orbital's shape.
   - Allowed values = 0 to (n-1) [dependent on the principal quantum number]
     - If n = 1, then l = 0. 0 to (1-1), 0 to 0
     - If n = 2, then l can be either 0 or 1. [Tells us about the number of sublevels]
     - If n = 3 then l can be either 0, 1, or 2.
   - Particular values of l are identified by a specific letter:

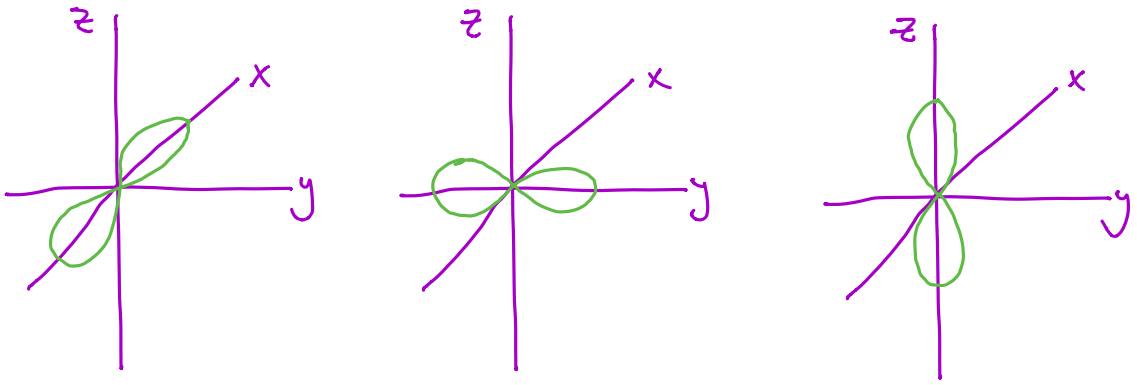
l	0	1	2	3
Orbital name	s	p	d	f

   - The shapes themselves are as follows:

- Electrons can have the __same__ *l* value, but it does not mean that they occupy the same orbital given that the orbital may have an __orientation__.
- To identify an energy sublevel, combination the principal quantum number with the angular movement
  - A sublevel with *n* = *3* and *l* = 0 is called __3S__.
  - A sublevel with n = 2 and *l* = 1 is called a __2p__.

3. The Magnetic Quantum Number (m_l)
   - Indicates the __orientation__ of the orbital around the nucleus.
   - Specifies the exact orbital within each __sublevel__.
   - Allowed values: __$-l$ to l__.
     - If *l* = 0, then m_l = 0
     - If l = 1, then m_l can be either: -1, 0, or 1.
     - If *l* = *2,* then m_l can be either: -2, -1, 0, 1, or 2.
   - There are exactly $2l + 1$ values of m_l.



4. The __Spin Quantum Number__ (m_s)
   - Specifies the direction of the electron spin: either __+ 1/2__ or __- 1/2__.
   - Note that an orbital can only hold 2 electrons of opposite spin.

Exercise

1. What are the possible quantum numbers for the first energy level

   a. Value of the first quantum number (n)? 1

   b. Possible values of the second quantum number (l)? 0 (s) (1s)

   c. Possible values of the third quantum number (m_l)? 0

   d. Possible values of the fourth quantum number (m_s)? $+1/2$ $-1/2$

   $n=1$, $l=0$, $m_l=0$, $m_s=+1/2$ → 1st electron

   $n=1$, $l=0$, $m_l=0$, $m_s=-1/2$ → 2nd electron

2. What are the possible quantum numbers for the second energy level

   a. Value of the first quantum number (n)? 2

   b. Possible values of the second quantum number (l)? 0 and 1

   c. Possible values of the third quantum number (m_l)? $l=0$, $m_l=0$

   $l=1$, $m_l=-1, 0, 1$

   d. Possible values of the fourth quantum number (m_s)? $+1/2$, $-1/2$

   $l=0$: 1st e⁻: $n=2$, $l=0$, $m_l=0$, $m_s=+1/2$; 2nd e⁻: $n=2$, $l=0$, $m_l=0$, $m_s=-1/2$

   $l=1$: 1st e⁻ $n=2$, $l=1$, $m_l=-1$, $m_s=+1/2$; 2nd e⁻ $n=2$, $l=1$, $m_l=0$, $m_s=+1/2$

3. How many electrons it is possible to find:

   a. In all of the n = 2 orbitals? (maximum)

   $n=2$, $l=0$, $m_l=0$ (2 electrons)

   $l=1$, $m_l=-1, 0, 1$ (6 electrons)

   } 8 electrons

   b. If we are given the quantum numbers $n = 2$ and $l = 1$?

   Three p orbitals, 6 electrons in total (at level 2)

   c. All of the p orbitals?

   Three p orbitals, 6 electrons in total

n = 1

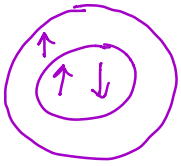
$n = 1,\ \ell = 0,\ m_\ell = 0,\ m_s = +1/2$

n = 1

1, 0, 0, +1/2

1, 0, 0, −1/2

n = 1

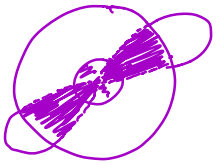


1s : 1, 0, 0, +1/2
1, 0, 0, −1/2

n = 2

2s : 2, 0, 0, +1/2

1s, 2s, and 2p orbitals.



n=1 s
n=2 s p
n=3 s p d

2, 1, −1, 1/2
↑
or
0
or
1